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Reports
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IMPACT OF RECREATIONAL DEVELOPMENT ON WATER QUALITY AND YIELD

Modified Study Plan
Eisenhower Consortium
Cooperative Agreement 16-784-GR
Research Work Unit No. FS-RM-1653(R&D)

Impact of Recreational Development on Water Quality and Yield

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STUDY PLAN

1. Problem Reference

This study is one of several areas of needed resource development research outlined in a 1973 Eisenhower Consortium Research Report,"Regional Environmental Management in West Texas and Eastern New Mexico: Resource Problems and Resource Opportunities," which was prepared as a joint effort by the current participants.

This project can be an important contribution to the knowledge needed by resource managers and land developers to minimize the extent of water pollution and variation in yield associated with disturbance of a virtually undisturbed mountain watershed. The study responds directly to the need to maintain high levels of water quality and optimum yield, commensurate with the ecological character of the watershed. Reduction of water treatment costs to downstream users results in increased opportunities for diversified water uses for a wide range of potential users.

Site Disturbance

Site disturbance associated with the development of homes in wildland areas can affect the water yield of the watershed in which the activity takes place. Also, the nature of the land clearing, excavation and related activities can result in deleterious impacts on water quality downstream from the activity. The magnitude of the site conversion over time influences use of the water for other than the flushing action of the stream.

Water deterioration, which limits use beyond the origin, impacts on public health, fisheries, contact recreation and visual qualities. The principal cause is silt and surface materials loading resulting from vegetation clearing, grading, excavation, blasting and construction on steep slopes. Dirt roads and bare construction sites are a source of large volumes

of soil and suspended materials. Construction litter and partially decayed solid waste and residue from improperly installed sewage systems result in other kinds of contaminants entering streams. The cumulative effect can often result in high levels of sediment loading, contamination of water quality and dimunition of the aesthetic and recreational values of downsite streams, lakes or manmade reservoirs. The public costs resulting from these activities can be significant.

2. Literature

Studies sponsored by the Council on Environmental Quality [1], the EPA [2], and the Bureau of Outdoor Recreation [3] have identified the trends toward expanded second home development and have expressed concerns for the effect of these developments on the environment. Ragatz [1] reported over 15 million residential lots within the United States in 1974, with new lots being added to those existing at the rate of 650,000 per year. States in the mountain West are expected to experience the greatest percent increase in future recreation homesite development.

The Western States, particularly the Southern Rocky Mountain Region, comprise an important part of the United States available for development due to the large expanses of undeveloped land, the unique natural beauty of the region, and the potential that large reserves of untapped energy and mineral resources represent future industrial growth. The region supports livelihoods from a multiplicity of private enterprises; ranching, mining, and forestry have been the main economic endeavors in the Southern Rocky Mountains and have contributed to keeping the population and industrial structures at a generally low level of development. In recent years, new recreational housing development forces have been accelerating the population

and economic growth of the Southern Rocky Mountains and are placing heavy loads on the environmental aspects of this region.

Healy [4] reported that the public has become concerned over the frantic pace of land development which has destroyed many amenities.

In some instances, local citizens have objected to the secondary homesite development. Deknatel [5] reported in the Voyager Village. Opposition to the Voyager Village, a secondary homesite expected to attract 10,000 - 13,000 people, came from the permanent residents. Their basic concerns were increased traffic, loss of natural resources, lake pollution from septic tank seepage and road runoff.

Among the impacts encountered in secondary homesites are those that adversely affect the land which, in turn, affects the ecosystem. McLean [6] reports that humans have accelerated many biogeographical changes by landscape transformations of natural areas by cutting, burning, and draining. The changes made to accommodate construction add to the overall pollution from non-point sources. McElroy, et.al. [7] regarded sediment resulting from soil erosion as the largest pollutant of water.

Khanna [8] has established the effects of highways on surface waters. Among the effects considered were (1) storm drainage, (2) effects on quantity of water and (3) effects on quality of water. A new highway or road has the potential to disturb the existing pattern of storm drainage in the area by increasing the runoff and cutting through the existing storm drainage pattern. Closely related to this is the effect on water quality. A highway or road construction project will increase the impervious paved area, thus substantially decreasing the time of concentration of flow and increasing the coefficient of runoff. This,

in turn, results in major increases in peak runoff and storm discharges. The effect on water quality results from erosion and sedimentation, which is the major cause of water pollution and environmental damage. The author suggests several steps be taken to mitigate this problem. Among the suggestions are uses of temporary erosion and sediment control measures, such as berms and dikes and timely planting of erosion control grasses and plants.

After the construction phase has been completed, the newly existing structures will effect the runoff. Schneider [9] reported that the lag time (time of concentration) is reduced as an area becomes urbanized, and the storm flow is often concentrated in sharper, shorter, higher peaks than those for natural runoff. The author further states that the effect of urbanization is a decline in ratio of urban peak rate to rural peak rate, with the urbanization being more pronounced for the more frequent occurrences.

Since developments in this region may have snowfall, the icing of roads could have an environmental impact. A study by Roth and Wall [10] has shown that road salt will slowly degrade vegetation along highway fringes, contaminate the soil, and be dominant among dissolved solids for months.

Miner [11] has shown that the presence of cattle may increase the concentration of bacteria in runoff and may prove to be significant in terms of total oxygen demand on the receiving stream. Bansal [12] has stated that the oxygen demand of nitrogenous wastes (such as microbiologically degraded cow manure) could substantially stress the oxygen resources of a slowly reaerating stream.

Past research has also dealt with other specific water quality and quantity parameters in runoff-related studies. Cowen [13] and Cowen and Lee

[14] examined nitrogen and phosphorus in urban runoff, and Dapper [15] studied pesticides in urban storm runoff. Other studies by Yen and Sakhlah [16] and Preul [17] address quantity relationships through mathematical model application.

Mertes, Carruthers and Renner [18] have reviewed the essentials of systems simulation as applied to resource management. Yoo and Molnau [19] have presented a model of runoff for erosion studies, a model comparable to the type invisioned for this research. Additionally, a report by Overton and Meadows [20] covers a generalized procedure for associating land use activities and design to undesirable outcomes such as flooding and stream water quality degradation. There is no straightforward method of reducing real world phenomena to abstract terms. Successful model building tends to be a function of the analyst's experience, trial and error procedures and luck. One difficulty with developing a simulation of small watershed yield and water quality will be accumulating sufficient analyst's experience in terms of observations to adequately specify the model.

These projects, along with other past and current research in the areas of urban and agricultural runoff water quantity and quality should be useful in addressing various aspects of this proposed research.

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[19] Yoo, Kyung Hak, and Myron Molnau, Modelling of Runoff for Erosion Studies, Idaho Water Resources Research Institute, Project A-047-IDA, June 1976.

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3. Objectives

The purpose of this study is to examine the impact on water yield and water quality of land conversion for recreational development in selected wildland watersheds in the Southern Rocky Mountains.

The specific objectives to be accomplished within the scope of this study are to:

1. Determine the relationships between changes in water quality and yield and the build-out rate of developments in mountain watersheds. This will be accomplished through:
   a. The establishment of sampling stations at the selected sites.
   b. The documentation of changes in land uses of the watersheds during the study period.
   c. The correlations of changes in water quality and yield with changes in the watershed.
2. Design, test and prepare as an operational package a general simulation model for evaluating possible effects of various types of developments in wildland watersheds on water quality and yield.
3. Prepare model performance standards for use by counties and/or private developers to minimize the dimunition of water quality and change in yield resulting from second home development.

4. Methods

The research will be conducted as follows:

Four study sites, part or all of which are developing toward one or more densities for recreational purposes have been selected in the Southern Rocky Mountain region. These sites are adjacent to Forest Service land in Region 3 and Region 2. The locations of the study sites are shown in Figure 1.

For each site the following data will be collected:

Land Use Analysis

This will involve an ecological and visual resource inventory of each study site prior to any construction disturbance beyond that required for primitive roads and/or trails. The inventory will map geology, soils, slope, vegetation, water, fauna, as well as any historical or cultural features. A history of past land use will be included. This will be prepared from aerial photographs, ownership archives, local documents, and personal recollections. Available water quality records and stream-flow data will be assembled and analyzed. Off-site uses and influences will be identified and analyzed in terms of their impact on the study site.

A complete photographic analysis of the site will be prepared in conjunction with an assessment of the visual absorption capacity of the site.

This data, which will be presented on single factor overlay maps, provides a graphic snapshot of the natural and cultural features of the site as they existed prior to land conversion.

Water Quality and Yield

I. Field monitoring of water quality and yield will be conducted at each site during the wet seasons (normally July, August, and September).

   A. Precipitation and runoff measurements will be made to determine effects of recreational development on yield.

   B. Surface and groundwater samples will be taken for chemical and biological analysis to determine quality changes.

   C. The minimum number of events to be included in the sampling program will depend on local meteorological conditions at the sites.

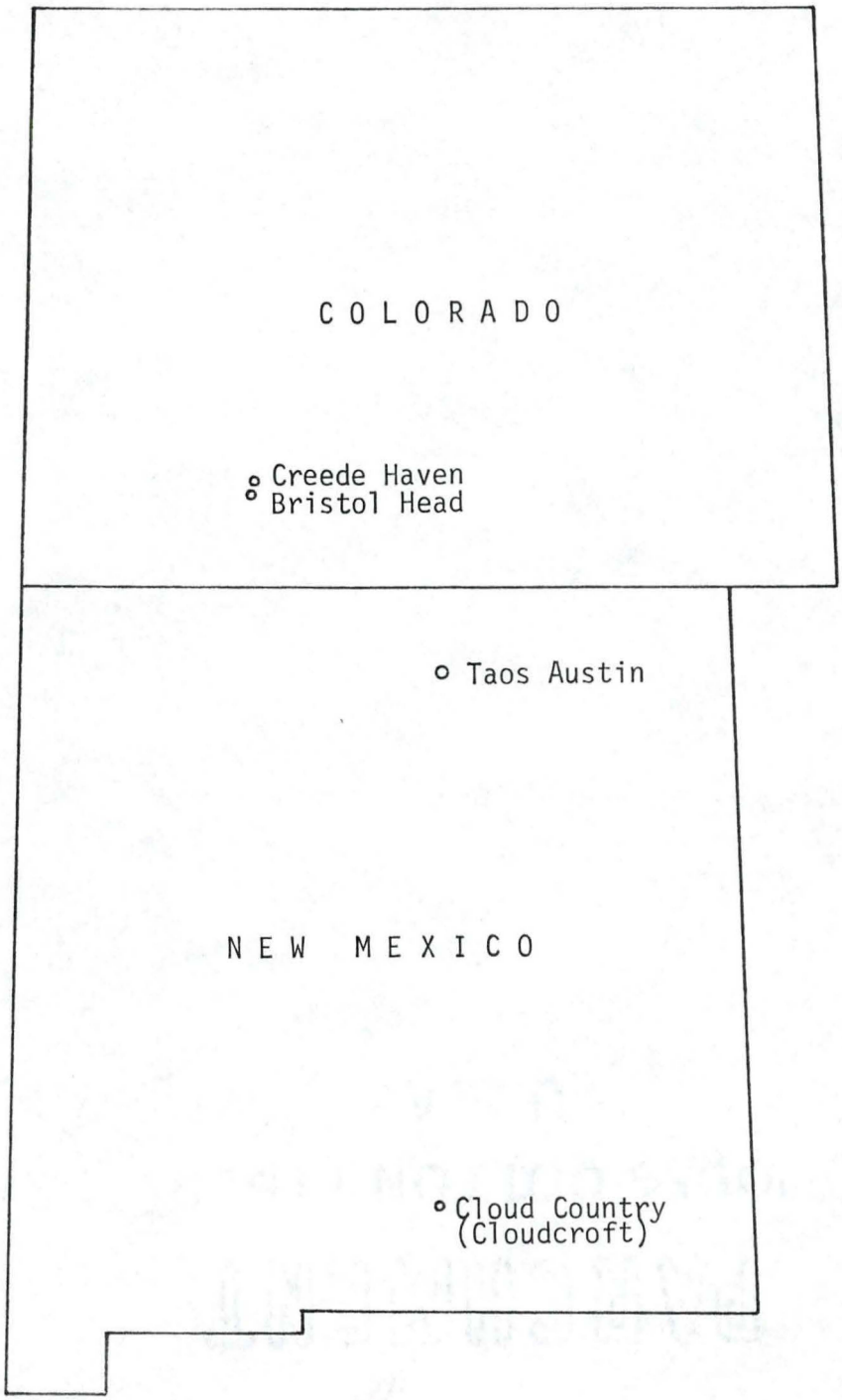


Figure 1. Location of study sites.

D. Degrees of freedom will be obtained from the number of sampled storm events. It is anticipated that this will amount to 8-10 events during each seasonal rainfall period.

E. Additional sampling will occur during other periods of the year as conditions develop (spring thaw, early rains, etc.)

II. Specific sampling and instrumentation requirements are described for each site in the following discussion.

A. Creede (Navajo Development Corp.) Site (Map No. 1).

1. Yield

a. Instrumentation requirements

(1) One recording rain gage (available on a loan basis).

(2) Four to five standard nonrecording gages

(3) Stream stage recorder (available on a loan basis).

(4) Four portable weirs.

b. Location of instruments

(1) Recording rain gage has been installed near center of development site.

(2) Nonrecording rain gages to be installed over watershed area.

(3) Stream gage has been installed on McCall Creek at the entrance to the site.

(4) Weirs have been placed above and below the development site.

(5) Submatic quality samplers.

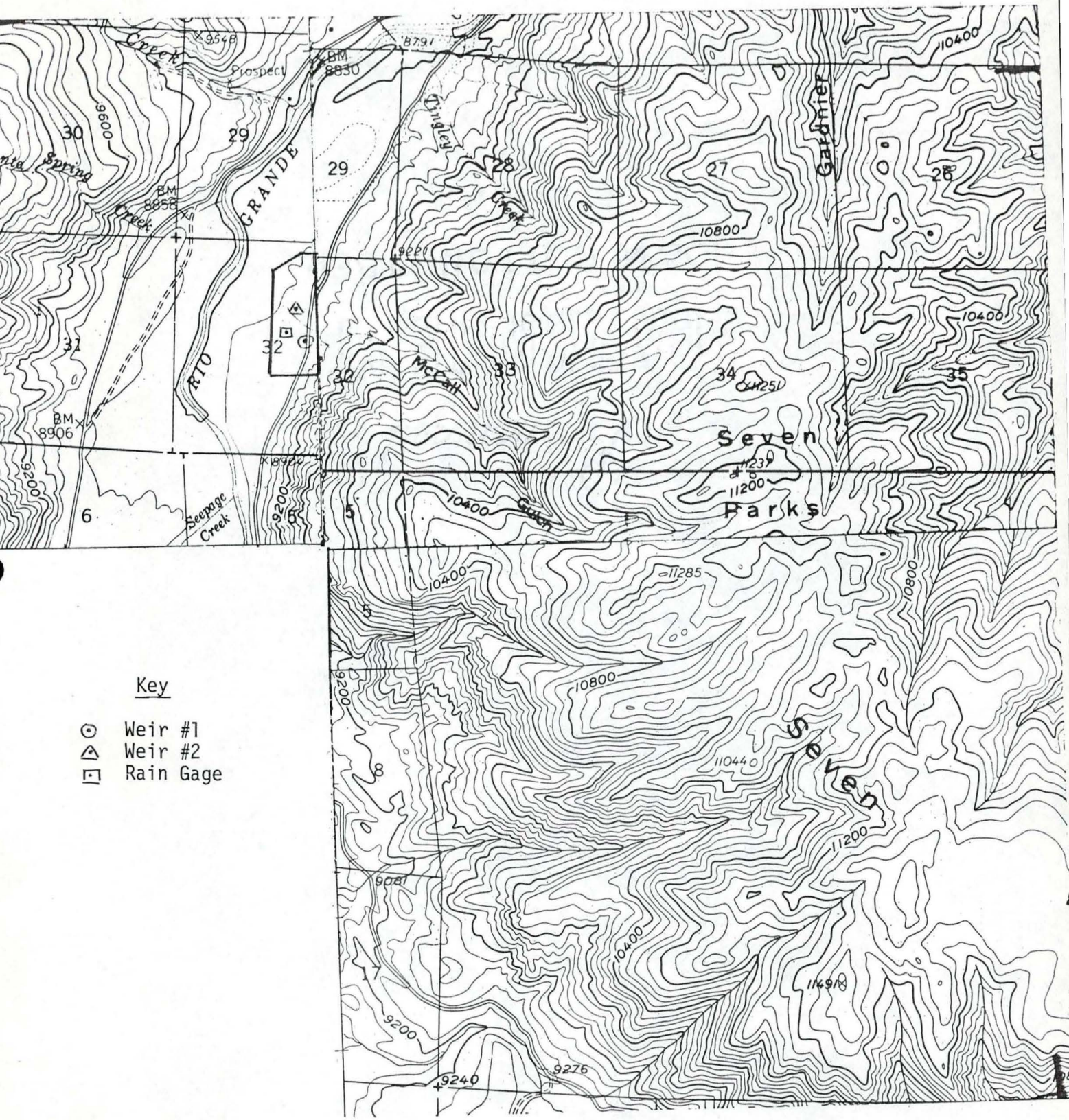
c. Data analysis

(1) Utilize Thiessen Method (or isohyetal method) to determine areal precipitation.

(2) Correlate with recording rain gage data to develop rainfall hydrographs.

(3) Determine runoff coefficient - intensity products from rainfall and runoff data.

(4) Determine changes in these products as development alters the hydrologic characteristics of the site.



Key

⊙ Weir #1
△ Weir #2
⊡ Rain Gage

Map No. 1. Creede Site

2. Quality

a. Instrumentation requirements

(1) Sample containers (additional units to be purchased).

(2) Reagents (for tests, sample preservation, etc. to be purchased as needed).

(3) Deep well grab sampler.

b. Location of sampling stations

(1) Above cow camp on McCall Creek (control).

(2) Below cow camp on McCall Creek.

(3) At each of the four weirs on the development site.

(4) From each of the two wells on the site.

c. Data analysis

(1) Samples taken by cooperators will be labeled, preserved, and sent to Texas Tech for analysis.

(2) Samples taken by project participants from Texas Tech will be analyzed both in the field and at Texas Tech.

(3) Data will be correlated with yield studies and will be analyzed for quality changes coincident with stages of development on the test site.

(4) The following parameters will be included in the quality studies: Coliforms, BOD, COD, total dissolved solids, nitrates, phosphates, chlorides, and heavy metals.

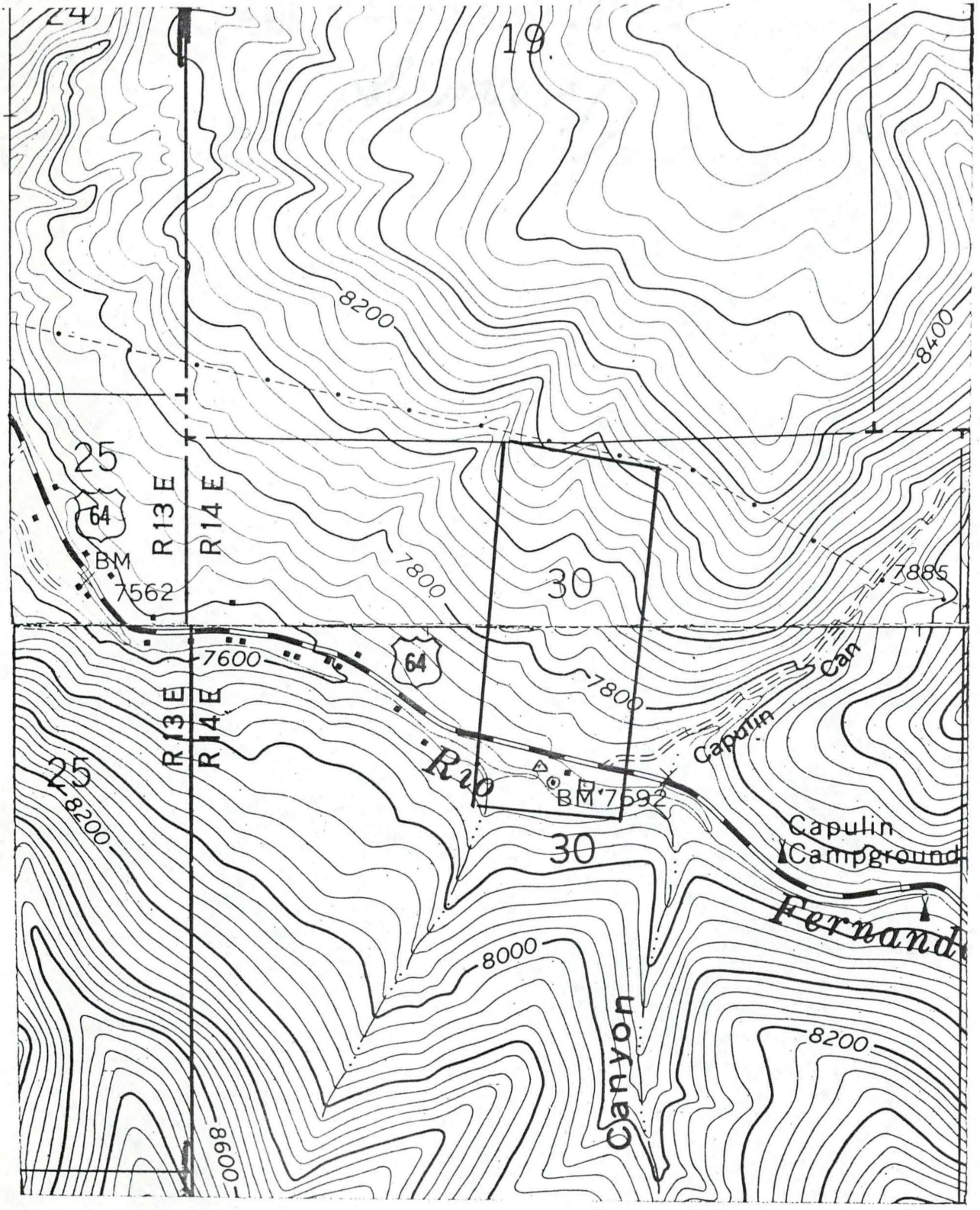
B. Taos Site (Map No. 2)

1. Yield

a. Instrumentation requirements

(1) One recording rain gage (available on a loan basis.

(2) Four to five standard nonrecording rain gages (to be constructed or purchased).



Map No. 2. Taos Austin Site

Key

⊙ Weir #1
△ Weir #2
⊡ Rain Gage

(3) Stream stage recorder (available on a loan basis).

(4) Two weirs have been installed.

b. Location of instruments (see attached map)

(1) Recording rain gage has been installed.

(2) Nonrecording rain gages to be installed over watershed area.

(3) Weirs have been placed in the development area.

c. Data analysis (see discussion for the Creede site).

2. Quality

a. Instrumentation requirements

(1) Sample containers (additional units to be purchased).

(2) Reagents.

b. Location of sampling stations

(1) At the mouth of Capulin Creek.

(2) Rio Fernando de Taos at the stream gaging station.

(3) At each of the two weirs on the development site. (by use of grab sampler)

(4) From the pumping well on the site.

c. Data analysis (see discussion for the Creede site).

C. Cloudcroft Site (Map No. 3)

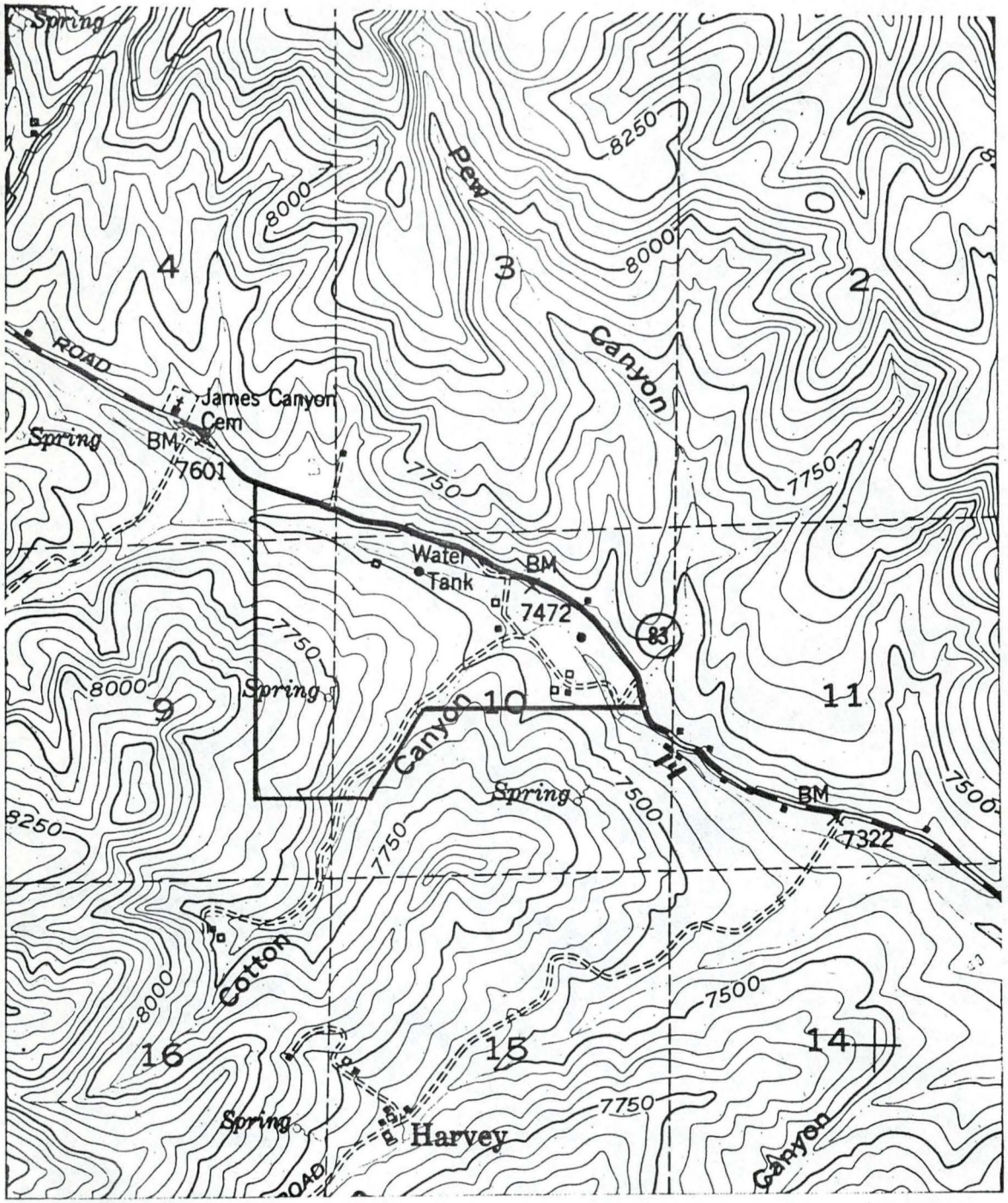
1. Yield

a. Instrumentation requirements

(1) One recording rain gage.

(2) Three to four standard nonrecording rain gages (to be purchased).

(3) Two stream stage recorders with weirs (recorders available on loan basis) weirs have been constructed.



Map No. 3. Cloudcroft Site

b. Location of instruments.

(1) Nonrecording rain gages to be installed with one gage in each area of the watershed with a unique infiltration-runoff coefficient combination.

(2) Stream gages to be placed as shown on the attached map.

c. Data analysis (see discussion for the Creede Site).

2. Quality

a. Instrumentation requirements

(1) Sample containers (additional units to be purchased).

(2) Reagents.

b. Location of sampling stations.

(1) At each of the two stream gaging sites (during runoff).

(2) From the subdivision water system (may use NMEIA* data).

c. Data analysis (see discussion for Creede Site).

Modeling

A simulation model, presented in Forrester symbology, will be developed following:

* Completion of a review of literature of similar runoff studies, and
* Preliminary results of above sampling activities which should reflect factors affecting runoff quantity and quality.

Model design will focus on those factors maniputable by resource managers, developers and landowners. The model will be tested by observing turning point errors in predicting outcomes from rainfall occurrences. After an acceptable model has been developed, the model will be used to simulate management options for mitigating detrimental aspects of second home development.

*NMEIA - New Mexico Environmental Improvement Agency

Performance Standards

Those factors identified in the simulation model will be used to develop a set of performance standards for avoiding activities which impact on water quality and yield in mountain developments. These standards will be prepared as language which can be incorporated into county zoning, subdivision, and related land management ordinances. Graphic illustrations will be prepared to interpret the performance standards.

5. Presentation of Expected Results

Expected results will be presented in a report format which utilizes graphic display techniques and statistical analysis to the fullest extent possible. The simulation model will be present in such a way as to facilitate use by nontechnically trained personnel. Instructions and appropriate examples will be provided so that a district ranger, county planner, engineering consultant or land developer could apply the model with minimal technical assistance as a tool in assessing the impact of a proposed land conversion on water quality and yield. Measurements taken from the study sites will demonstrate the expected impact of a similar type of development under approximate conditions. Illustrations of specific aspects of the impact of the activity will be incorporated into the report.

6. Personnel Assignment, Time of Completion and Cost

Personnel Assignment

1. Investigators

James D. Mertes
Lloyd V. Urban
Garrey E. Carruthers
Robert S. Freeburg
Robert M. Sweazy

Time devoted as necessary to complete the research in the designated time.

2. Graduate Assistants

James Duncan (Doctoral Candidate)
One-half time for 24 months.

3. Secretarial

Staff of the Water Resources Center, Texas Tech University and New Mexico Water Resources Research Institute available as needed.

Time of Completion

Proposed Time Schedule.

December 5, 1977 - Initiate Study

January 9, 1978 - Work on Study Plan

February 28, 1978 - Submit Study Plan

March 15, 1978 - Secure automatic samplers from Forest Service (RMS to provide instruments)

May 20, 1978 - September 30, 1979 - Field data collection and analyses

June 1978 - September 30, 1979 - Prepare simulation model and performance standards

October 1979 - December 1979 - Preparation of final report

Cost

As per agreement EC 16-784-GR the project cost is $30,000.

7. Appendix

Necessary Operations

It may be helpful to secure cooperation from local Forest Service personnel in the form of field assistance to check on the instruments installed at the study sites. Some of the instruments will be on private land. The landowner cooperators have expressed a willingness to assist the investigators in taking instrument readings and water samples. In some instances these individuals would not be available at the frequency required to properly service the instruments as well as repair any minor breakage or vandalism. Forest Service personnel would be permitted access to the private property for purposes of assisting the investigators. Because the Forest Service personnel would be readily available whenever the need arises, the investigators

could depend on reliable and accurate service of the instrument stations. Limitations of funding restrict the frequency of site visitations by the investigators, particularly if the rainfall occurs at frequent intervals.

In discussions with the Forest Service the investigators indicated the need to secure automatic samplers for the water quality analysis. The Forest Service was asked to procure four samplers which would be used by the investigators then returned to the Forest Service at the conclusion of the study. Dr. Gordon Lewis, Program Manager for the Eisenhower Consortium was asked to work through the Rocky Mountain Station to secure the instruments, and agreed to take care of this. These instruments cannot be purchased by the investigators because of the level of funding for the study. It was determined by the Rocky Mountain Station that they could use the instruments for other research within the station.

Choice of Instruments

The instrument package includes those devices which can collect the information needed to analyze the impact of site disturbance on water quality and yield. A list of the instruments to be used in this study is provided in Appendix A.

APPENDIX A

1. Automatic Samplers with spare bottles and carrying cases:

   This equipment which has been requested from the Forest Service is required to provide a means of obtaining water samples at specific time intervals throughout the duration of runoff produced by a precipitation event. Standard equipment includes twenty-four bottles, which would be sufficient to collect samples at fifteen minute intervals for six hours. Spare bottles and carrying case will make it possible to change the bottles after six hours and continue to collect samples on a continuous basis; or during periods of sample analysis. Due to the remoteness of candidate sites, refrigerated units may be necessary for sample preservation. Units will be required to collect samples from various locations over the sites.

2. Recording Rain Gages:

   This equipment is required to provide a record of precipitation events at the sites, which would then be compared to runoff data in order to determine hydrologic changes from development.

3. Automatic Stage Recorders:

   This equipment is required to obtain quantitative information regarding the rate at which runoff is produced by a precipitation event. It is expected that the quality of runoff will vary considerably with the duration, rate, and total quantity of runoff produced and this equipment will make it possible to relate runoff quality and quantity.

APPENDIX B

Location of Suitable Areas (Sites)

The four proposed study sites were selected on the basis of several factors. These are:

1. Sites which are presently undisturbed, but scheduled for some construction activity during the time frame of the study.
2. Prior association by investigator Freeburg with the subject landowners has led to a amicable working relationship. These landowner cooperators have indicated a willingness to cooperate with the investigators in all aspects of the study, including assistant in data collection.
3. Each of the sites is adjacent to a National Forest which allows for the assessment of a control watershed.
4. The sites are representative of typical dispersed and heavily concentrated second home recreation development which has and is taking place throughout the Southern Rocky Mountain region.

Criteria for site selection are as follows:

The criteria used as a basis for site selections and a listing of sites meeting those criteria are given in the following table.

SITE SELECTION CRITERIA AND DEVELOPMENTS* WHICH MEET CRITERIA

Planned Development Density			Planned Amenity Level		
Low	Medium	High	Low	Medium	High
B.H.	C.H. or C.C.	T.A. or C.H.	B.H.	T.A. or C.H.	C.C.

Type of Dwelling				Topography		
Permanent		Seasonal				
Custom	Prefab.	Rec. Veh.	Mobile Home	Flat	Med. Slope	Steep Slope
C.H. or C.C.	B.H.	T.A.	T.A.	B.H. or C.H.	T.A.	C.C. or T.A.

*See Symbol List on following page.

Vegetation Type		
Forested	Combin.	Open
C.C. or T.A.	T.A.	B.H. or C.H.

Symbol List:

B.H. = Bristol Head
C.C. = Cloud Country
C.H. = Creede Haven
T.A. = Taos Austin

U. S. FOREST SERVICE

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